TITLE OF THE INVENTION

INFORMATION STORAGE MEDIUM, INFORMATION RECORDING
METHOD, AND INFORMATION RECORDING/REPRODUCTION
APPARATUS

5          CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the
benefit of priority from the prior Japanese Patent
Application No. 2001-143530, filed May 14, 2001, the
entire contents of which are incorporated herein by
10    reference.

BACKGROUND OF THE INVENTION

1.  Field of the Invention

The present invention relates to a high-density
information recording technique using a focused beam
15    (blue laser or the like).  More particularly, the
present invention relates to an improvement in an
information recording method for a high-density optical
disc on/from which digital information is
recorded/reproduced at constant linear velocity (CLV).
20    Also, the present invention relates to an inter-layer
crosstalk reduction technique in a recordable optical
disc having a recording multilayer including two or
more layers per side.

2.  Description of the Related Art

25    As a high-density information storage capable of
repeated recording (repeated rewrite) using a focused
beam, optical discs such as a DVD-RAM, DVD-RW, and the

like is known.

<<Problem 1>>

In a DVD-RW (rewritable medium), new data is recorded by partially overwriting an already data recorded portion (Restricted Overwrite). In this case, since already recorded data is partially destroyed to record the next data, the reliability of information recorded on an information storage medium suffers considerably.

<<Problem 2>>

On the other hand, a DVD-RAM (repeated recordable medium) suffers the following problems:

a) Since data are recorded between neighboring ones of a large number of prepit headers present on an information storage medium, the information recording efficiency (recording density) lowers, thus disturbing large capacity.

b) When a two-recording layer structure per side is adopted for large capacity, inter-layer crosstalk is generated due to prepit headers, thus deteriorating reproduction signal characteristics. That is, in a recording layer, since recorded and unrecorded portions have a light reflectance difference, inter-layer crosstalk in which the presence/absence of recording marks on the other recording layer influences a reproduction signal is generated, thus deteriorating reproduction signal characteristics.

## BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention, predetermined recording units (e.g., 16 to 32 sectors/ECC blocks of 32 to 64 kbytes) are recorded to

5      have a gap ($\delta$) therebetween. Since the gap ($\delta$) is formed, even when a rotation driving mechanism (spindle motor) of a medium suffers rotation nonuniformity, neighboring recording units can be prevented from overlapping each other, thus preventing recorded data

10     from being destroyed (due to some recording marks destroyed when the neighboring recording units overlap each other), and maintaining high reliability of recorded data.

According to another aspect of the present

15     invention, in this invention using a one-sided, recording multilayer type disc-shaped medium (e.g., one-sided, two-layered optical disc 9) which has spiral tracks with track pitch Pt, data recording is done via an objective lens having numerical aperture NA and an

20     intermediate layer which has refractive index n and thickness t. This data recording is made to form a gap ($\delta$) between predetermined recording units (ECC blocks). If $D = 2t \tan\{\sin^{-1}(NA/n)\}$, length $\delta$ of the gap is given by "$\delta \leq \pi(D + Pt)D/Pt$".

25     According to still another aspect of the present invention, upon successively recording data for respective predetermined recording units (ECC blocks)

along spiral tracks on a disc-shaped information

storage medium having a rotation center, a gap ($\delta$) is

formed between the predetermined recording units

(ECC blocks) along the tracks.  In at least one pair of

5    neighboring tracks of the tracks, the angular position

of the gap ($\delta$) formed on one of the neighboring tracks

with respect to the rotation center is different from

the angular position of the gap ($\delta$) formed on the other

one of the neighboring tracks with respect to the

10    rotation center.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a view for explaining a data recording

method on an information storage medium (recordable

optical disc using a blue laser) according to an

15    embodiment of the present invention;

FIG. 2 is a view for explaining inter-layer

crosstalk in the information storage medium (one-sided,

two-layered type) according to the embodiment of the

present invention;

20    FIG. 3 is a view for explaining the configuration

of physical sector data recorded on the information

storage medium according to the embodiment of the

present invention;

FIG. 4 is a view for explaining a method of

25    forming an ECC block with respect to physical sector

data shown in FIG. 3;

FIG. 5 is a view for explaining the internal

structure of an ECC block recorded on the information

storage medium according to the embodiment of the

present invention;

FIG. 6 is a block diagram for explaining the

5    arrangement of an information recording/reproduction

apparatus according to the embodiment of the present

invention;

FIG. 7 is a flow chart for explaining the format

sequence in the ECC block structure in FIG. 4;

10    FIG. 8 is a view for explaining a data recording

method on an information storage medium (recordable

optical disc using a blue laser) according to another

embodiment of the present invention;

FIG. 9 is a view for explaining necessity of a gap

15    (groove gap) in the information storage medium

according to the present invention;

FIG. 10 is a view for explaining a data recording

method on an information storage medium (recordable

optical disc using a blue laser) according to still

20    another embodiment of the present invention;

FIG. 11 is a view for explaining the maximum

allowable range of gaps (groove gaps) on the

information storage medium according to the present

invention;

25    FIG. 12 is a view for explaining an information

storage medium formed with a mark that determines a

recording start position according to still another

embodiment of the present invention;

FIG. 13 is a flow chart for explaining a recording method or rewrite method in the information recording/reproduction apparatus according to the

5 embodiment of the present invention; and

FIG. 14 is a flow chart for explaining a process for forming gap $\delta$ in the recording method according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

10 An information storage medium, information recording method, and information recording/reproduction apparatus according to various embodiments of the present invention will be described hereinafter with reference to the accompanying

15 drawings.

FIG. 1 is a view for explaining the basic concept of a data recording method on information storage medium (recordable optical disc using a blue laser) 9 according to an embodiment of the present invention.

20 FIG. 2 schematically shows the structure of this information storage medium (one-sided, two-layered type) 9.

When information storage medium 9 in FIG. 1 is of one-sided, two-layered type shown in (a) of FIG. 2, for

25 example, phase change type first recording layer 123 is formed on substrate 90 of medium 9, intermediate layer 124 which has thickness t and refractive index n is

formed thereon, phase change type 0th recording layer
122 is formed thereon, and transparent protection layer
125 (having a thickness of about 100 μm) is formed
thereon.

5    On information storage medium 9 shown in FIGS. 1
and 2, fine pre-grooves are spirally or concentrically
formed as embossed patterns, and form tracks 112.  By
forming recording marks 127 (in (b) of FIG. 2) on the
recording layer (122 or 123 in (a) of FIG. 2) along
10   tracks 112, information is recorded.

In this embodiment, information is recorded or
rewritten for respective continuous data recording
units (110a, 110b, and 110c in FIG. 1) where recording
marks 127 are continuously formed, thus forming
15   recording marks 127.  In this case, gaps 111b and 111c
with length δ are formed between neighboring continuous
data recording units 110a, 110b, and 110c.  In this
way, the gist of the data recording method according to
this embodiment resides in formation of predetermined
20   gap δ between neighboring data recording units.

When gaps 111b and 111c are formed between
neighboring continuous data recording units 110a, 110b,
and 110c, as shown in FIG. 1, these gaps (δ) absorb the
influence (jitter) of rotation nonuniformity of a
25   spindle motor (204 in FIG. 6 to be described later)
that rotates disc-shaped medium 9.  That is, since this
gap (e.g., 111b) is formed, even when large jitter is

produced due to rotation nonuniformity of a rotation driving system upon information recording, an overlapping portion can be prevented from being formed between neighboring continuous data recording units

5 (e.g., 110a and 110b), and data in each continuous data recording unit 110 can be stably and easily rewritten. This is a large feature obtained by the data recording method that forms gap δ between neighboring data recording units.

10 This embodiment adopts CLV (Constant Linear Velocity) recording in which length δ of each gap 111 and length L of each continuous data recording unit 110 always become constant independently of the radial position in information storage medium 9. A data

15 structure in continuous data recording unit 110 is formed by recording synchronization VFO (Variable Frequency Oscillator) area 113 formed at the beginning of continuous data recording unit 110, and recording area 114 which follows area 113.

20 Note that the contents of recorded information 114 in FIG. 1 are obtained by modulating and recording data of one whole ECC block (e.g., data as a combination of small ECC block 8-0 in (f) of FIG. 4 to be described later and small ECC block 8-1 in (g) of FIG. 4).

25 However, the contents upon practicing the present invention are not limited to these contents. For example, the practice contents of the present invention

include a case wherein recorded information 114 is made up of a plurality of ECC blocks or of a fraction of an integer of data in one ECC block. Alternatively, one recorded information 114 may be formed of one or a

5 plurality of pieces of physical sector information 4 shown in FIG. 3 (to be described later).

A great reduction effect of inter-layer crosstalk on one-sided, two-recording layer type information storage medium 9 by the recording method in FIG. 1 will

10 be explained below using FIG. 2.

For example, a case will be examined below wherein laser beam (its wavelength $\lambda$ is around 405 nm) 120 is focused on first recording layer 123 via objective lens 121 (its numerical aperture NA is, for example, around

15 0.85), and information recorded on first recording layer 123 is reproduced by detecting a change in amount of light reflected by first recording layer 123, as shown in (a) of FIG. 2. At this time, some light components of laser beam 120 are reflected by 0th

20 recording layer 122, pass through objective lens 121 again, and leak into detection light.

As described above in <<Problem 2>> of the prior art, already recorded and unrecorded portions (inside and outside recording marks 127) in recording layers

25 122 and 123 have a light reflectance difference. Therefore, the amount of light which is reflected by 0th recording layer 122 and leaks into detection light

changes considerably between a case wherein 0th

recording layer 122 is completely unrecorded and has no

recording marks 127, and a case wherein data have

already been recorded on the entire surface of 0th

5     recording layer 122 and recording marks 127 are

distributed everywhere.  The change in amount of light

which is reflected by 0th recording layer 122 and leaks

into detection light is reflected by first recording

layer 123 and leaks into a reproduction signal used to

10    reproduce information (inter-layer crosstalk), thus

deteriorating reproduction signal characteristics.

     Let D be the diameter of laser beam 120 that

strikes 0th recording layer 122, NA be the numerical

aperture of objective lens 121, n be the refractive

15    index of intermediate layer 124, and t be the thickness

of intermediate layer 124 under the condition that the

laser beam is focused on first recording layer 123

shown in (a) of FIG. 2.  Then, since:

$$NA = n \sin \theta \qquad \qquad \ldots (1)$$

20    
$$D = 2t \tan \theta \qquad \qquad \ldots (2)$$

we have

$$D = 2t \tan\{\sin^{-1}(NA/n)\} \qquad \ldots (3)$$

     A case will be examined below wherein a plurality

of neighboring gaps 111 align in the radial direction

25    (perpendicular to tracks 112) of optical disc 9, as

shown in (b) of FIG. 2.

     If $\delta > D$, laser beam 120 may completely fall

within the region where the plurality of neighboring
gaps 111 align (not shown).  At this time, the region
of laser beam 120 with diameter D contains no recording
marks 127 at all, i.e., corresponds to an unrecorded

5    state (which will be referred to as state $\alpha$ hereinafter
for the sake of simplicity).

If laser beam 120 with diameter D has moved to a
position largely separated from the region where gaps
111 align, the entire surface within the region of

10   laser beam 120 with diameter D is filled with recording
marks 127 (this state will be referred to as state $\beta$
hereinafter).

As described above, since regions inside and
outside each recording mark 127 have a light

15   reflectance difference, the amounts of laser beam 120
reflected by 0th recording layer 122 in states $\alpha$ and $\beta$
have a large difference, and very large inter-layer
crosstalk occurs consequently.

By contrast, if $\delta \leq D$, i.e., a state that

20   satisfies:

$$\delta \leq 2t \ \tan\{\sin^{-1}(NA/n)\} \qquad \qquad ...(4)$$

is set, since the region where gaps 111 align is
present only on a portion within the region of laser
beam 120 with diameter D, a change in amount of laser

25   beam 120 reflected by 0th recording layer 122 (i.e.,
inter-layer crosstalk) when laser beam 120 passes by
the region where gaps 111 align becomes smaller than

the difference between states $\alpha$ and $\beta$ described above.

In this manner, since gaps 111b and 111c are laid out between neighboring continuous recording units 110a, 110b, and 110c, and gaps 111b and 111c are set to have small length $\delta$, an inter-layer crosstalk amount upon reproduction of one-sided, multi-layered disc can be reduced.  A large characteristic feature of this embodiment lies in this point.

Note that the inter-layer crosstalk reduction effect appears remarkably when:

$$\delta \leq D/2 \quad (\text{i.e., } \delta \leq t\tan\{\sin^{-1}(NA/n)\}) \quad \ldots(5)$$

As a result of further tests and evaluations, when $\delta$ is limited to fall within the range:

$$\delta \leq D/4 \quad (\text{i.e., } \delta \leq t\tan\{\sin^{-1}(NA/n)\}/2) \quad \ldots(6)$$

a condition that suffers less characteristic deterioration of a reproduction signal (suffers less influence of inter-layer crosstalk) can be obtained.

For example, when NA = 0.85, n = 1.57, and t = 50 $\mu$m, gap $\delta$ is $\delta \leq 64$ $\mu$m from inequality (4). On the other hand, $\delta \leq 32$ $\mu$m from inequality (5), and $\delta \leq 16$ $\mu$m from inequality (6).

As described above, in the embodiment of the present invention, data are recorded along tracks by CLV.  Hence, at a radial position where the length per round of information storage medium 9 deviates from an integer multiple of length $L + \delta$ (i.e., the physical periodic length of gaps 111 which align at intervals in

the direction along tracks 112), the positions of gaps 111 are different from each other between neighboring tracks.

By contrast, at a radial position where the length per round of information storage medium 9 matches an integer multiple of length $L + \delta$ (physical periodic length of gaps 111), gaps 111 are arranged at neighboring positions between neighboring tracks, and gap regions 111 align in the radial direction of information storage medium 9, as shown in (b) of FIG. 2. At such radial position, the physical periodic length of gaps 111 is changed in the direction along tracks 112 to lay out gaps 111 at non-neighboring positions between neighboring tracks. A characteristic feature of the present invention also lies in this point.

FIG. 3 is a view for explaining the configuration of physical sector data recorded on the information storage medium according to the embodiment of the present invention. FIG. 4 is a view for explaining a method of forming an ECC block with respect to physical sector data shown in FIG. 3. The concept associated with the structure in an ECC block in the embodiment of the present invention will be explained below with reference to FIGS. 3 and 4.

AV information and stream information, which are transferred continuously, are broken up into small

pieces, which are converted into pack structures appended with pack headers, and these packs are recorded on information storage medium (optical disc) 9. That is, as shown in (a) of FIG. 3, video

5 information and audio information are transferred while being arranged along the time axis in the form of video packs 1-0, 1-1, 1-2,..., and audio packs 2-0, 2-1, 2-2,.... Each of video packs 1-0,... and audio packs 2-0,... has a data size of 2048 bytes, which match the

10 logical sector information size. Video packs 1-0,... and audio packs 2-0,... are abstractly handled as a plurality of pieces of logical sector information 3-1 to 3-31 in the logical layer, as shown in (b) of FIG. 3. (That is, examples of practical contents of

15 the plurality of pieces of logical sector information 3-1 to 3-31 correspond to video packs 1-0,... and audio packs 2-0,....)

In the embodiment shown in FIGS. 3 and 4, since physical sector information and logical sector

20 information match, these pieces of information are handled as a plurality of pieces of physical sector information 4-0 to 4-31, as shown in (c) of FIG. 3.

As will be described in detail later, each physical sector information (4-0 to 4-31) has the

25 following configuration. That is, 4-byte PID information, 2-byte IED information, and a 10-byte reserve field (the size in an existing DVD is 6 bytes)

are arranged at the head of each information, and
4-byte EDC is arranged at the end of information (data
0-0-0 to data 0-0-5). After that, that sequence is
broken up into 188-byte data (each of data 0-0-0 to

5    data 0-0-5), error correction PI (inner-code parity)
data (PI0-0-0 to PI0-0-5) are appended to every
188-byte data, and these data are arranged in turn,
as shown in (d) of FIG. 3 or (d) of FIG. 4. In
odd-numbered physical sector data (first physical

10   sector data 5-0), PO (outer-code parity) data (PO0) is
arranged at the end of data to complete physical sector
data 5-0.

The embodiment of the present invention is
characterized in that even-numbered physical sector

15   data (second physical sector data 5-1) has a structure
in which PO data (PO1) is arranged in the second column
from the end of data, and data 1-1-5 and PI data
(PI1-1-5) are arranged at the end of the even-numbered
physical sector data. Physical sector data 5-0 to

20   5-31, which are completed in this manner, are recorded
on an optical disc (information storage medium 9) in
accordance with the order they are arranged, as shown
in (e) of FIG. 3.

As shown in (d), (f), and (g) of FIG. 4, one

25   physical sector data 5-0 is formed as a combination of
data in two different small ECC blocks 8-0 and 8-1.
(In this embodiment, ECC blocks 8-0 and 8-1 (small

units) shown in (f) and (g) of FIG. 4 are called small

ECC blocks, and a combination of two small ECC blocks

8-0 and 8-1 as a whole is called a general ECC block.)

More specifically, data in physical sector data

5      5-0 is finely broken up into 200-byte data, and

188-byte data 0-0-0 and PI data 0-0-0 are arranged in

the first row in ECC block 8-0.  Next 188-byte data

0-1-0 and PI 0-1-0 in physical sector data 5-0 are

arranged in the first row in small ECC block 8-1.

10     Furthermore, next 188-byte data 0-0-1 and PI data 0-0-1

are arranged on the second row in ECC block 8-0.

Of PO data in small ECC block 8-1, first 200 bytes are

inserted in the sixth row in small ECC block 8-1

as PO0.  As a result, data from data 0-0-0 to PO0

15     form physical sector data 5-0.

First data 1-0-0 and PI 1-0-0 that follows the

first data in next physical sector data 5-1 are

arranged in the seventh row in ECC block 8-0, as shown

in (f) of FIG. 4.  Of PO data in ECC block 8-0, first

20     200-byte data is arranged as PO1 in the 12th row in ECC

block 8-0.

In this way, PO data (PO0, PO1) for respective

rows (200 bytes) are arranged at equal intervals for

respective physical sector data 5-0 to 5-31, and their

25     arrangement positions have a difference for one

physical sector data between a pair of small ECC blocks

8-0 and 8-1.

FIG. 5 is a view for explaining the internal structure of an ECC block recorded on the information storage medium according to the embodiment of the present invention.  FIG. 5 exemplifies the detailed

5 structure in small ECC block 8-0 or 8-1 shown in (f) or (g) of FIG. 4.  Note that the numerals assigned to "sectors" in FIG. 5 indicate row numbers of data sectors.

The right side of FIG. 5 shows a combined state of

10 two, right and left (for each 200-byte column) small ECC blocks.  Each small ECC block has a structure in which 12-byte PI data is appended every 188 bytes, and PO data for 16 rows is appended.  The PO data for 16 rows is decomposed into row data, each of which is

15 interleaved and inserted at every 12-row positions. A hatched portion of 200-byte columns per row in FIG. 5 means interleaved and inserted PO data.

The user information size assigned per sector is 2048 bytes as in an existing DVD, and information

20 having the same contents as those of logical sector information recognized in the application layer is set as each physical sector information (main data). Four-byte data ID information, 2-byte IED information, and 10-byte reserve field (the size in an existing DVD

25 is 6 bytes) are arranged at the head of 2048 bytes of the main data (physical sector information), and 4-byte EDC data is arranged at the end of the main data, thus

forming all data of a physical sector.

Since one physical sector data is interleaved across two small ECC blocks (i.e., within a general ECC block), an error-correctable burst error length can be improved to nearly twice that of the prior art. That is, one physical sector data is broken up into 188-byte data, each of which forms one row data by appending 12-byte PI data (since the existing PI size is 10 bytes, and is increased to 12 bytes, error correction performance per row can be improved), and these row data are alternately and sequentially arranged in right and left different ECC blocks. This is also one of the characteristic features of this embodiment.

Data (data sector) in one physical sector has an odd number of rows, i.e., 11 rows. This is also a characteristic feature of this embodiment. Since the data sector is made up of an odd number of rows, the total number of rows can be even upon inserting one PO row in each physical sector, and the PO row can be properly inserted in two small ECC blocks (i.e., one general ECC block) without forming any odd row.

PID information is always arranged at the head position (upper left corner position in FIG. 5) of each physical sector, and the PO insert positions are devised to allow efficient interleave insertion of PO data in the embodiment shown in FIG. 5. That is, PO

data is arranged at the last row position of an even

sector, and PO data is arranged at the second row

position from the end of the sector in an odd sector.

As a result, PO data are arranged in a single ECC

5    block, and all physical sectors can have the same data

size.   This is also a characteristic feature of this

embodiment.

The arrangement of an information

recording/reproduction apparatus according to the

10    embodiment of the present invention will be described

below with reference to FIG. 6.

1.   Function of information recording/reproduction unit

1-1.   Basic function of information

recording/reproduction unit

15    An information recording/reproduction unit

executes the following processes are done.   That is,

* the unit records new information or rewrites

(or erase) information at a predetermined position on

information storage medium (optical disc) 9 using

20    a focused beam spot; and

* the unit reproduces already recorded information

from a predetermined position on information storage

medium (optical disc) 9 using a focused beam spot.

1-1-1.   Basic function achieving means of information

25    recording/reproduction unit

As means for achieving the above basic functions,

the information recording/reproduction unit executes

the following processes.   That is,

* the unit traces a focused beam spot along tracks
112 on information storage medium 9;

* the unit switches recording/reproduction/erase

5      of information by changing the amount of light of
a focused beam spot with which information storage
medium 9 is irradiated; and

* the unit converts externally input recording
signal d into an optimal signal to record it at high

10     density and with a low error rate.

2.   Structure of mechanism portion and operation of
detection portion

2-1.   Basic structure of optical head 202 and signal
detection circuit

15     2-1-1.   Signal detection by optical head 202

Optical head 202 basically comprises a
semiconductor laser element (not shown) as a light
source, a photodetector, and an objective lens.
A laser beam emitted by the semiconductor laser element

20     is focused on information storage medium (optical disc)
9 via the objective lens (121 in FIG. 2).   The laser
beam reflected by a light reflection film or light
reflective recording film (122 or 123 in FIG. 2) of
information storage medium (optical disc) 9 is

25     photoelectrically converted by the photodetector.
A detection current obtained by the photodetector
undergoes current-voltage conversion by amplifier 213

to obtain a detection signal. This detection signal is processed by focus/track error detection circuit 217 or binarization circuit 212.

In general, the photodetector is divided into a plurality of photodetection regions, which individually detect changes in amount of light with which the respective photodetection regions are irradiated. Respective detection signals undergo sum/difference calculations by the focus/track error detection circuit 217, thus detecting focus and track errors. In this way, a change in amount of light reflected by the light reflection film or light reflective recording film of information storage medium (optical disc) 9 is detected, thereby reproducing signal c on information storage medium 9.

2-1-2. Objective lens actuator structure

The objective lens (121 in FIG. 2) that focuses a laser beam emitted by the semiconductor laser element on information storage medium 9 is movable in two axis directions in accordance with an output current from objective lens actuator driving circuit 218. The objective lens moves:

* in a direction perpendicular to information storage medium 9 to correct focus errors; and

* in the radial direction of information storage medium 9 to correct track errors.

Such objective lens moving mechanism is called

an objective lens actuator.

2-2A. Rotation control system (zone CAV rotation control) of information storage medium (optical disc)

Information storage medium (optical disc) 9 is
mounted on turn table 221 which is rotated by the
driving force of spindle motor 204. The rotational
speed (rotational velocity) of information storage
medium 9 is detected based on a reproduction signal
obtained from information storage medium 9. That is,
the detection signal (analog signal) output from
amplifier 213 is converted into a digital signal by
binarization circuit 212, and PLL (Phase Lock Loop)
circuit 211 generates a constant period signal
(reference clock signal) based on that digital signal.
Information storage medium rotational speed detection
circuit 214 detects the rotational speed of information
storage medium 9 using this signal, and outputs the
detection value.

A correspondence table of the information storage
medium rotational speed which corresponds to the radial
position where data is reproduced or recorded/erased on
information storage medium 9 is pre-stored in
semiconductor memory 219. When a reproduction position
or record/erase position is determined, controller 220
sets a target rotational speed of information storage
medium 9 by looking up information recorded in
semiconductor memory 219, and sends that value to

spindle motor driving circuit 215.

Spindle motor driving circuit 215 calculates the difference between this target rotational speed and the output signal (current rotational speed) of information storage medium rotational speed detection circuit 214, and supplies the driving current corresponding to that difference to spindle motor 204, thus controlling the rotational speed of spindle motor 204 to be constant. The output signal from information storage medium rotational speed detection circuit 214 is a pulse signal having a frequency corresponding to the rotational speed of information storage medium 9, and spindle motor driving circuit 215 controls both the frequency and pulse phase of this signal.

2-2B. Rotation control system (CLV rotation control) of information storage medium (optical disc)

Information storage medium (optical disc) 9 is mounted on turn table 221 which is rotated by the driving force of spindle motor 204. The rotational speed (rotational velocity) of information storage medium 9 is detected based on a reproduction signal obtained from a wobbled groove region (143 in FIG. 12 or the like) present on information storage medium 9. That is, the detection signal (analog signal) output from focus/track error detection circuit 217 is converted into a digital signal by a binarization circuit (not shown) in information storage medium

rotational speed detection circuit 214, thus generating a constant period signal (reference signal). Rotational speed detection circuit 214 detects the rotational speed of information storage medium 9 using this reference signal, and outputs a difference signal corresponding to the frequency/phase difference between that detection value and a reference clock signal. Based on this difference signal output value, spindle motor driving circuit 215 supplies a predetermined driving current to spindle motor 204 to make control to attain a constant linear velocity (CLV).

2-3. Optical head moving mechanism

To move optical head 202 in the radial direction of information storage medium 9, optical head moving mechanism (feed motor) 203 is equipped.

3. Functions of respective control circuits

3-1. Focused beam spot trace control

In order to perform focus or track error correction, a circuit for supplying a driving current to an objective lens actuator (not shown) in optical head 202 in accordance with the output signal (detection signal) from focus/track error detection circuit 217 is arranged. This circuit is objective lens actuator driving circuit 218. This circuit 218 includes a phase compensation circuit for improving characteristics in correspondence with the frequency characteristics of the objective lens actuator to

attain quick response of objective lens movement up to
the high frequency range.

In response to a command from controller 220,
objective lens actuator driving circuit 218 executes:

5     * an ON/OFF process of focus/track error
correction operation (focus/track loop);

    * a process for moving the objective lens at low
speed in a direction (focus direction) perpendicular to
information storage medium 9 (executed when focus/track

10   loop is OFF); and

    * a process for moving a focused beam spot to a
neighboring track by slightly moving in the radial
direction (direction to cross tracks) of information
storage medium 9 using a kick pulse.

15   4.  Various operations associated with control system
of mechanism portion

4-1.  Startup control

When information storage medium (optical disc) 9
is mounted on turn table 221 and startup control is

20   started, the processes are executed in accordance with
the following sequence.

1)  Controller 220 sends a target rotational speed
to spindle motor driving circuit 215, which supplies
a driving current to spindle motor 204, thus starting

25   rotation of spindle motor 204.

2)  At the same time, controller 220 issues
a command (execution command) to feed motor driving

circuit 216, which supplies a driving current to
optical head driving mechanism (feed motor) 203,
thus moving optical head 202 to the innermost
peripheral position of information storage medium 9.

5      At that time, it is confirmed if optical head 202
has reached an inner peripheral portion beyond
the information recording region on information storage
medium 9.

3)   When spindle motor 204 has reached the target

10      rotational speed, that status (status report) is output
to controller 220.

4)   Semiconductor laser driving circuit 205
supplies a current to the semiconductor laser element
in optical head 202 in correspondence with a

15      reproduction light amount signal sent from controller
220 to recording/reproduction/erase control waveform
generation circuit 206, thus starting laser emission.

Note that an optimal irradiation light amount upon
reproduction varies depending on the types of

20      information storage media (optical discs) 9.   Upon
startup, the lowest irradiation light amount value of
those values is set.

5)   The objective lens (121 in FIG. 2) in optical
head 202 is moved to a position farthest from

25      information storage medium 9, and objective lens
actuator driving circuit 218 is controlled to make the
objective lens slowly approach information storage

medium 9.

6) At the same time, focus/track error detection circuit 217 detects a focus error amount, and outputs status to controller 220 when the objective lens has

5  reached near an in-focus position.

7) Upon receiving that status, controller 220 issues a command to objective lens actuator driving circuit 218 to enable the focus loop.

8) Controller 220 issues a command to feed motor

10  driving circuit 216 while the focus loop is ON to slowly move optical head 202 toward the outer periphery of information storage medium 9.

9) At the same time, a reproduction signal from optical head 202 is monitored, and when optical head

15  202 has reached the recording region on information storage medium 9, controller 220 stops movement of optical head 202, and issues a command to objective lens actuator driving circuit 218 to enable the track loop.

20  10) An "optimal light amount upon reproduction" and "optimal light amount upon recording/erase" recorded on the inner peripheral portion of information storage medium (optical disc) 9 are reproduced, and are recorded in semiconductor memory 219 via

25  controller 220.

11) Furthermore, controller 220 sends a signal corresponding to that "optimal light amount upon

reproduction" to recording/reproduction/erase control waveform generation circuit 206, thus re-setting the emission amount of the semiconductor laser element upon reproduction.

12) The emission amount of the semiconductor laser element upon recording/erase is set in correspondence with the "optimal light amount upon recording/erase" recorded on information storage medium 9.

4-2. Access control

4-2-1. Reproduction of access destination information on information storage medium 9

Information that indicates locations and contents of information recorded on storage medium 9 varies depending on the types of information storage medium 9, and is generally recorded in directory management regions, navigation packs, or the like in information storage medium 9. Note that the directory management regions are recorded together in the inner or outer peripheral region of information storage medium 9. On the other hand, the navigation pack is contained in a VOBS (Video Object Set) complying with the data structure of a PS (Program Stream) of MPEG2, and records information indicating the location of the next video data.

When specific information is to be reproduced or recorded/erased, information in the above-mentioned

region (information indicating the locations and contents of information recorded) is reproduced, and an access destination is determined based on the reproduced information.

5    4-2-2.  Coarse access control

Controller 220 calculates the radial position of the access destination, and detects the distance between that position and the current position of optical head 202.  As for the moving distance of

10   optical head 202, velocity curve information that allows the head to reach the target position within a shortest period of time is stored in advance in semiconductor memory 219.  Controller 220 reads that information, and controls movement of optical head 202

15   by the following method in accordance with the velocity curve.

More specifically, controller 220 issues a command to objective lens actuator driving circuit 218 to disable the track loop, and then controls feed motor

20   driving circuit 216 to start movement of optical head 202.  When the focused beam spot has crossed a track on information storage medium 9, focus/track error detection circuit 217 generates a track error detection signal.  Using this track error detection

25   signal, the relative velocity of the focused beam spot with respect to information storage medium 9 can be detected.  Feed motor driving circuit 216 calculates

the difference between the relative velocity of the focused beam spot obtained from focus/track error detection circuit 217, and target velocity information sent from controller 220, and feeds back that result to the driving current to be supplied to optical head driving mechanism (feed motor) 203, thus moving optical head 202.

In "optical head moving mechanism (feed motor) 203" mentioned above, a frictional force always acts between a guide shaft and bushing or bearing (not shown). When the optical head moves at high speed, dynamic friction acts. However, since the moving velocity of optical head 202 is low at the beginning of movement and immediately before stop, static friction acts. At that time, since the relative frictional force increases, the amplification factor (gain) of a current to be supplied to optical head driving mechanism (feed motor) 203 is increased in response to a command from controller (especially, immediately before stop).

4-2-3. Fine access control

When optical head 202 has reached the target position, controller 220 issues a command to objective lens actuator driving circuit 218 to enable the track loop. The focused beam spot reproduces an address or track number of that portion while tracing along a track on information storage medium 9. The current

focused beam spot position is detected from that address or track number, and controller 220 calculates the number of error tracks from the reached target position and informs objective lens actuator driving

5 circuit 218 of the number of tracks required to move the focused beam spot. When objective lens actuator driving circuit 218 generates a pair of kick pulses, the objective lens slightly moves in the radial direction of information storage medium 9, thus moving

10 the focused beam spot to the neighboring track.

In objective lens actuator driving circuit 218, the track loop is temporarily disabled, and after kick pulses are generated a given number of times corresponding to the information from controller 220,

15 the track loop is enabled again. Upon completion of fine access, controller 220 reproduces information (address or track number) at the position where the focused beam spot traces, and confirms if it has accessed a target track.

20 4-3. Continuous recording/reproduction erase control

As shown in FIG. 6, a track error detection signal output from focus/track error detection circuit 217 is input to feed motor driving circuit 216. "Upon startup control" and "upon access control" mentioned above,

25 controller 220 controls feed motor driving circuit 216 not to use the track error detection signal. After it is confirmed that the focused beam spot has reached

the target track by access, some components of
the track error detection signal are supplied as
a driving current to optical head driving mechanism
(feed motor) 203.  This control continues during the
period in which a reproduction or recording/erase
process is done continuously.

Note that information storage medium 9 is mounted
so that its central position has a slight eccentricity
from that of turn table 221.  When some component of
the track error detection signal are supplied as a
driving current, entire optical head 202 slightly moves
in correspondence with the eccentricity.  When the
reproduction or recording/erase process is continuously
done for a long period of time, the focused beam spot
position gradually moves toward the outer or inner
periphery.  When some components of the track error
detection signal are supplied as a driving current to
optical head moving mechanism (feed motor) 203, optical
head 202 gradually moves toward the outer or inner
periphery in correspondence with that current.  In this
manner, the load on track error correction of the
objective lens actuator is reduced, thus attaining
a stable track loop.

4-4.  End control

When a series of processes are complete and the
operation is to be ended, the process is done in
accordance with the following sequence.  That is,

1) controller 220 issues a command to objective lens actuator driving circuit 218 to disable the track loop;

2) controller 220 issues a command to objective lens actuator driving circuit 218 to disable the focus loop;

3) controller 220 issues a command to recording/reproduction/erase control waveform generation circuit 206 to stop emission of the semiconductor laser element; and

4) controller 220 informs spindle motor driving circuit 215 of zero reference rotational speed.

5. Flow of recording signal/reproduction signal to information storage medium

5-1. Signal format recorded on information storage medium 9

In order to meet requirements:

* of correcting recording information errors caused by defects on information storage medium 9;

* of simplifying a reproduction processing circuit by setting zero DC component of a reproduction signal; and

* of recording information at highest possible density on information storage medium 9

for a signal to be recorded on information storage medium 9, the information recording/reproduction unit (physical system block) performs "addition of an error

correction function" and "signal conversion of recording information (signal modulation/demodulation)", as shown in FIG. 6.

5-2.  Flow of signal upon recording

5     5-2-1.  ECC (Error Correction Code) appending process

Information to be recorded on information storage medium 9 is input to data input/output interface 222 as recording signal d in the form of a raw signal. This recording signal d is directly recorded in

10    semiconductor memory 219, and then undergoes an ECC appending process, as described above, in ECC encoding circuit 208.

Upon completion of appending of inner-code PI and outer-code PO, ECC encoding circuit 208 reads data for

15    one sector from semiconductor memory 219, and transfers the read data to modulation circuit 207.

5-2-2.  Signal modulation

In order to make a DC component (DSV: Digital Sum Value) of a reproduction signal approach 0 (zero), and

20    to record information on information storage medium 9 at high density, signal modulation as conversion of a signal format is done in modulation circuit 207. Modulation circuit 207 and demodulation circuit 210 include a conversion table indicating the relationship

25    between a source signal and modulated signal.  The signal transferred from ECC encoding circuit 208 is segmented into data each consisting of a plurality of

bits in accordance with a modulation scheme, and the segmented data are converted into other signals (codes) by looking up the conversion table.

For example, when 8/16 modulation (RLL (2, 10) code) is used as the modulation scheme, two different types of conversion tables are present, and the conversion table to be looked up is switched as needed to make the DC component (DSV) after modulation approach zero.

5-2-3. Recording process on information storage medium 9

Semiconductor laser driving circuit 205 operates to record information from optical head 202 on information storage medium 9. At this time, as shown in FIG. 1 and (b) of FIG. 2, recording marks 127 are continuously formed along tracks 112 for respective continuous data recording units 110, and gaps 111 are formed between neighboring continuous data recording units 110.

Note that each continuous data recording unit (110, 131) is made up of one whole ECC block (130a) or a fraction of an integer (e.g., 133 or 134 in FIG. 8) of one ECC block (130b), as shown in FIG. 8. Note that "a fraction of an integer of one ECC block" indicates a case wherein one ECC block (130b) contains a plurality of physical sectors (e.g., 7-0 to 7-31 in FIG. 8), and a fraction of an integer of the plurality

of physical sectors (7-0 to 7-15 or 7-16 to 7-31; 1/2

in this case) form one continuous data recording unit

(133 or 134).

5-3. Flow of signal upon reproduction

5 5-3-1. Binarization/PLL circuit

As described in "signal detection by optical head

202", a change in amount of light reflected by the

light reflection film or light reflective recording

film of information storage medium (optical disc) 9 is

10 detected to reproduce a signal on information storage

medium 9. Binarization circuit 212 converts that

signal into a binary digital signal consisting of "1"

and "0" using a comparator.

From the reproduction signal obtained by the

15 binarization circuit, PLL circuit 211 extracts

a reference signal upon reproducing information.

PLL circuit 211 incorporates a variable frequency

oscillator. The frequency and phase of a pulse signal

(reference clock) output from the oscillator are

20 compared with those of the output signal from the

binarization circuit 212, and the comparison results

are fed back to the oscillator output.

5-3-2. Signal demodulation

Demodulation circuit 210 incorporates a conversion

25 table (not shown) indicating the relationship between

modulated and demodulated signals. A modulated signal

is restored to an original signal by looking up the

conversion table in synchronism with the reference
clock obtained by PLL circuit 211. The restored
(demodulated) signal is recorded in semiconductor
memory 219.

5  5-3-3. Error correction process

Error correction circuit 209 detects any errors of
a signal saved in semiconductor memory 219 using
inner-code PI and outer-code PO, and sets pointer flags
of error positions. After that, error correction

10 circuit 209 corrects a signal at the error positions in
accordance with the error pointer flags while reading
out the signal from semiconductor memory 219, removes
inner-code PI and outer-code PO, and transfers the
signal to data input/output interface 222. A signal

15 sent from ECC encoding circuit 208 is output as
reproduction signal c from data input/output
interface 222.

Parameters used in the control sequences of
respective processes and the respective processes in

20 the apparatus shown in FIG. 6 are written in control
program/parameter ROM 220b in controller 220 as
firmware. A microprocessing unit MPU (not shown) of
controller 220 executes a control program in ROM 220b
using worm RAM 220a as a work area, thus executing the

25 aforementioned processes.

The format process sequence executed in the
apparatus shown in FIG. 6 will be explained below using

the flow chart shown in FIG. 7. This process is executed in ECC encoding circuit 208 shown in FIG. 6, and detailed control is made by controller 220. FIG. 7 shows the sequence of the data conversion process (format conversion process) shown in FIGS. 3 to 5.

Initially, physical sector information is set (step ST1). With this setting, a plurality of pieces of physical sector information 4-0 to 4-31 ((c) of FIG. 3) are set (segmented into main data in units of 2048 bytes). In this case, the plurality of pieces of physical sector information 4-0 to 4-31 are set in correspondence with the size of a plurality of pieces of logical sector information 3-0 to 3-31 ((b) of FIG. 3). That is, user data to be recorded is handled in units of 2048 bytes.

Subsequently, a 2068-byte data sector is generated from 2048-byte main data, 16-byte auxiliary data, and a 4-byte error detection code (EDC) (step ST2). Note that the 16-byte auxiliary data contains 4-byte data ID data (PID), a 2-byte error detection code (IED) for the data ID, and 10-byte reserve data (RSV).

Note that the PID records a sector number used to identify a data sector, and sector information used to identify the contents of the data sector. The IED is used to detect any errors generated in the PID portion. The RSV is used to record other kinds of auxiliary information (e.g., copyright management information).

The EDC is used to detect any errors generated in 2064-byte main data and auxiliary data.  The data sectors are arranged in a 188 (columns) × 11 (rows) matrix.

5      Scramble data is added to 2048-byte main data of each data sector (step ST3).

Data sector rows are re-arranged depending on whether the sector number is even or odd (step ST4).

A sector block is generated by vertically stacking 10 32 continuous data sectors, which are re-arranged depending on their sector numbers (step ST5).  The data sectors which are vertically stacked are arranged in a 376 (columns) × 176 (rows) matrix.

The sector block is horizontally segmented into 15 two blocks to encode error correction codes (step ST6). Note that the 188 (columns) × 176 (rows) blocks after segmentation undergo encoding in the column direction to generate outer-code parity data (PO) for 16 rows. This outer code uses a REED Solomon code of RS(192, 20 176, 17).  Subsequently, inner-code encoding is done in the row direction to generate inner-code parity data (PI) for 12 columns.  This inner code uses a REED Solomon code of RS(200, 188, 13).

The ECC block undergoes row interleave to 25 distribute 16 right and left rows of PO data into the block (step ST7; see FIG. 5).  In this case, 32 rows (= 16 × 2) of PO data are distributed row by row

to sectors. At this time, PO rows of the left block of the two horizontally segmented blocks are inserted after the lowermost row of an odd sector consisting of only five rows, and PO rows of the right block of the two horizontally segmented blocks are inserted after the lowermost row of an even sector consisting of only five rows.

With the aforementioned process, physical sector data is completed (step ST8).

Subsequently, zigzag recording across two rows is done (step ST9).

A modulation process is executed (step ST10). In this case, if a bit sequence of data to be recorded is directly recorded on medium 9, the characteristic feature of the recording data sequence does not match the recording characteristics of medium 9, and efficient recording cannot be done. In consideration of the recording characteristics of medium 9, a data pattern is converted according to a predetermined conversion rule. For example, the modulation scheme includes an 8/16 modulation scheme for converting 1-byte data into a 16-bit pattern, an 8/12 modulation scheme for converting 1-byte data into a 1.5-byte pattern, a 12/18 modulation scheme for converting 12-bit data into an 18-bit pattern, and the like. Any one of these schemes comprises a plurality of conversion tables and a logic circuit for selecting

the conversion table. Especially, since the 12/18 modulation scheme that converts 1.5-byte data has a characteristic of expanding an error at one position to 1.5 bytes, it is effective for the process executed in step ST9 to distribute errors upon reproduction.

Via steps ST1 to ST10, zigzag recording according to the setup in step ST9 is done for medium 9. In this recording, data recording is continuously done for respective continuous data recording units 110, as shown in FIG. 1. In this case, recording is controlled to form gaps 111 with length $\delta$ between neighboring continuous data recording units 110.

FIG. 8 is a view for explaining the data recording method on the information storage medium (recordable optical disc using a blue laser) according to another embodiment of the present invention.

The physical data length of recording information 114 in FIG. 1 nearly matches the data length (the length of ECC block 130a in FIG. 8) after modulation of data of the ECC block shown in FIGS. 3 and 4, as described above.

When a radial position where the length per round of information storage medium 9 matches an integer multiple of length $L + \delta$ has been reached, ECC block 130b is segmented into two blocks, and continuous data recording unit 131b which is obtained by appending VFO field 113b to former half data 133 of ECC block 130b to

have physical length J is recorded in the direction of tracks 112.

Gap 111c with length δ is formed after such continuous data recording unit 131b, and continuous data recording unit 131c obtained by appending VFO field 113c to latter half data 133 of ECC block 130b to have physical length J is recorded after gap 111c in the direction of tracks 112. As can be seen from FIG. 8, since length "δ + J + δ + J" is different from length L + δ, gaps 111 do not come to neighboring positions between neighboring tracks (112a and 112b) at that radial position (the radial positions of tracks 112a and 112b in FIG. 8).

In FIG. 8, the half of data obtained by modulating ECC block 130b is recorded and arranged in continuous data recording unit 131. However, the scope of the present invention is not limited to this. For example, a plurality of arbitrary physical sector data (7-0 to 7-15 and 7-16 to 7-31 in the example in FIG. 8) may be recorded and arranged, or a plurality of ECC blocks 130 may be recorded and arranged together in single continuous data recording unit 131.

FIG. 9 is a view for explaining necessity of gaps (groove gaps) δ in the information storage medium according to the present invention.

A problem posed when δ assumes too small a value will be explained below using FIG. 9. When spindle

motor 204 shown in FIG. 6 is free from any rotation

nonuniformity (ideal state), pairs of continuous data

recording units 110 and gaps 111 are recorded along

tracks 112 without any variations of length (L + δ), as

5 shown in (a) of FIG. 9. However, when the rotational

speed of spindle motor 204 locally increases (due to

rotation nonuniformity), the end position of continuous

data recording unit 110a shifts backward, and gap 111b

is narrowed down. Furthermore, in the worst case, the

10 end position of continuous data recording unit 110a may

enter the head position of continuous data recording

unit 110b that has already been recorded at the

subsequent location, and data overlap portion 116 may

be generated.

15 When recording layers 122 and 123 of information

storage medium 9 are made up of a phase-change type

recording film, data overlap portion 116 is overwritten

by rear data of leading continuous data recording

unit 110a, and first data of continuous data recording

20 unit 110b is destroyed.

Rotation control of spindle motor 204 is made

using a wobble signal obtained from wobbled groove 143

shown in FIG. 12. Therefore, let f be the rotation

nonuniformity amount of spindle motor 204, and τ be the

25 wobble period of wobbled groove 143. Then, the shift

amount of last data of continuous data recording

unit 110a due to rotation nonuniformity of spindle

motor 204 is given by "$\tau f$".

Therefore, in order to avoid the problem resulting from the data overlap portion shown in (b) of FIG. 9, length $\delta$ of gap 111 must be set to satisfy:

5       $\delta \geq \tau f$                     ...(7)

The rotation nonuniformity amount of spindle motor 204 (the practical rotation nonuniformity amount, including the influence of eccentricity, of optical disc 9, which is actually set on table 221 rotated by

10   motor 204) normally depends on the eccentricity of information storage medium 9. If the eccentricity of information storage medium 9 is $\pm 100$ $\mu$m, rotation nonuniformity amount f due to this eccentricity is around 0.1%. In this case, inequality (7) is

15   rewritten as:

      $\delta \geq 0.001\tau$                    ...(8)

Inequality (7) or (8) can define the lower limit of gap $\delta$, and inequality (4), (5), or (6) mentioned above can define the upper limit of gap $\delta$.

20   Note that the value of gap $\delta$, the lower limit of which is defined by inequality (7) or (8) cannot often satisfy inequality (6) ($\delta \leq D/4$ or $\delta \leq \tau\tan\{\sin^{-1}(NA/n)\}/2$) mentioned above due to (practical) rotation nonuniformity of spindle motor 204 or other

25   factors. A measure against such case will be explained below.

As described above in (b) of FIG. 2, when long gap

regions 111 with length δ align in the radial direction
of information storage medium 9, inter-layer crosstalk
takes place.  This inter-layer crosstalk becomes
conspicuous with increasing length δ of gap 111

5      (if δ = 0, no inter-layer crosstalk due to gaps 111
occurs).  Hence, if length δ of gaps 111 cannot be
shortened due to rotation nonuniformity or the like,
the positions of gaps 111 shift, i.e., gaps 111 are
arranged at non-neighboring positions between

10     neighboring tracks, thus reducing inter-layer
crosstalk.  One of examples of such position shift
methods of gaps 111 has already been explained with
reference to FIG. 8.  In addition, as an example of the
position shift method of gaps 111, a method shown in

15     FIG. 10 is available.

FIG. 10 shows an application (modification) of
FIG. 8.  In FIG. 8, the physical periodic length of
gaps 111 is changed to lay out gaps 111 at
non-neighboring positions between neighboring tracks

20     (112a and 112b).  Alternatively, in FIG. 10, the
physical periodic length of gaps 111 is not
macroscopically changed, but the position of gap 111 is
shifted at only a position where gaps may be located at
neighboring positions between neighboring tracks (112a

25     and 112b).

In FIG. 10, at many locations in information
storage medium 9, each ECC block 130b is segmented into

two blocks, 16 sectors from physical sectors 7-0 to
7-15 are assigned to continuous data recording unit
131b as former half data 133 of ECC block 130b, and
another 16 sectors from physical sectors 7-16 to 7-31

5    are assigned to continuous data recording unit 131c as
latter half data 134 of ECC block 130b.

    At the radial position (that satisfies inequality
(7)) of information storage medium 9 at which gaps 111
are located at neighboring positions (position of point

10   A) between neighboring tracks with this layout method,
the position of gap 111e is shifted to the position of
point B.

    That is, at this location (position of point B),
15 sectors from physical sectors 8-1 to 8-14 are

15   assigned to continuous data recording unit 137 as
former half data 133 of ECC block 130c.  As a result,
the physical length of continuous data recording
unit 137 is shortened from "J" to "J - $\alpha$".  At the same
time, 17 sectors from physical sectors 8-15 to 8-31 are

20   assigned to continuous data recording unit 138 as
latter half data 134 of ECC block 130c.  As a result,
the physical length of continuous data recording
unit 132 is prolonged from "J" to "J + $\alpha$".
As a result, the position of gap 111e is shifted.

25    In this way, the numbers of sectors to be stored
in continuous data recording units 137 and 138 are
changed before and after gap 111e (i.e., the total

length of continuous data recording units 137 + 138 remains the same, but the lengths of continuous data recording units 137 and 138 are changed by $\pm\alpha$), thus shifting the position of gap 111e from a neighboring position of point A to point B.

In the embodiment shown in FIG. 8, data obtained by segmenting ECC block 130 into 1/M data is assigned to one of continuous data recording units 131 to 133. In the embodiment shown in FIG. 10, ECC block 130 is segmented into two data (M = 2), which are assigned to the continuous data recording units. However, this embodiment is not limited to this, and other values such as 4, 8, 16, and the like may be used as the value M.

The aforementioned conditions of inequalities (4) to (6) are met only when gaps 111 align in the radial direction, as shown in (b) of FIG. 2. Let L be the physical length of continuous data recording unit 110 in the direction along tracks 112 of information storage medium 9. Then, the condition of inequality (6) is satisfied only when the center of laser beam 120 traces a position of radius $r_0$ which satisfies:

$$N(L + \delta) = 2\pi r_0 \qquad \ldots (9)$$

with respect to integer value N.

However, at the position of radius r ($r \neq r_0$), since we generally have:

$$N(L + \delta) = 2\pi r - \zeta \qquad \ldots (10)$$

the positions of gaps 111 do not align but shift from each other, as shown in FIG. 11.

FIG. 11 is a view for explaining the maximum allowable range of gaps (groove gaps) on the information storage medium according to the present invention.

The embodiment of the present invention adopts CLV (Constant Linear Velocity) as the recording method. In FIG. 11, the central position of gap 111 or 115 at the position of radius r of information storage medium 9 will be considered as a reference.

Let Pt be the track pitch. Then, the shift amount between the central positions of gaps 111 or 115 on neighboring tracks in the direction along the tracks (in the circumferential direction of information storage medium 9) is given by:

$$2\pi Pt + \zeta \qquad \qquad \dots (11)$$

In FIG. 11, the shift amount of the central position of gap 111 or 115 at the m-th track position counted from a track with radius r from the gap central position at the immediately preceding track position is given by:

$$2\pi Pt \cdot m + \zeta \qquad \qquad \dots (12)$$

For this reason, total shift amount X from the reference position (central position of gap 111 or 115 at the position of radius r) is given by:

$$X = \Sigma \{2\pi Pt \cdot m + \zeta\} \qquad \qquad \dots (13)$$

As in the case of (b) of FIG. 2, the spot diameter of laser beam 120 that causes the influence of inter-layer crosstalk is also D in FIG. 11. Since the number of tracks included within length D is D/Pt, the total of equation (13) is obtained by calculating the sum from m = 0 to m = D/Pt and is given by:

$$X = \pi Pt(D/Pt)(D/Pt + 1) + \zeta D/Pt$$

$$= \{\pi(D + Pt) + \zeta\}D/Pt \qquad \qquad ...(14)$$

If gaps 111a to 111f with sufficiently small length $\delta 2$ are present in FIG. 11, the influence of inter-layer crosstalk may be relatively small. By contrast, if gaps 115a to 115f with sufficiently large length $\delta 1$ are present, no recording mark is present within most of the area in laser beam 120 in the state shown in FIG. 11, and large inter-layer crosstalk appears.

As shown in FIG. 11, when start position G of gap 115a located at the endmost position in laser beam 120, and end position H of gap 115f located at the opposite end position in laser beam 120 align in the radial direction (positions G and H nearly match in the circumferential direction), the influence of inter-layer crosstalk appears clearly. In this case, the distance from the central position of gap 115a to start position G is equal to that from the center of gap 115f to end position H, i.e., $\delta 1/2$. As a result, X = $\delta 1$ at that time and, from equation (14), we have:

$$\delta 1 = \{\pi (D + Pt) + \zeta\} D/Pt \qquad \qquad ...(15)$$

Therefore, since a condition that can reduce the influence of inter-layer crosstalk in the state shown in FIG. 11 is $\delta \leq \delta 1$, we have:

5

$$\delta \leq \{\pi (D + Pt) + \zeta\} D/Pt \qquad \qquad ...(16)$$

Since the average at every positions on information storage medium 9 is:

$$\zeta = (L + \delta)/2 \doteqdot L/2 \qquad \qquad ...(17)$$

substitution of equation (17) into inequality (16)

10 yields:

$$\delta \leq \{\pi (D + Pt) + L/2\} D/Pt \qquad \qquad ...(18)$$

In a minimum state, since $\zeta = 0$, inequality (16) is rewritten as:

$$\delta \leq \pi (D + Pt) D/Pt \qquad \qquad ...(19)$$

15 That is, inequality (19) must be satisfied as the inter-layer crosstalk reduction that pertains to length $\delta$ of gaps.

FIG. 12 is a view for explaining an information storage medium formed with a mark that determines a

20 recording start position according to still another embodiment of the present invention.

Recording start position determination mark 141 recorded on information storage medium 9 is reproduced by optical head 202 in FIG. 6, and is sent to

25 focus/track error detection circuit 217 via amplifier 213. In focus/track error detection circuit 217, the presence/absence of mark 141 is detected as

a given component of a track error detection signal.
Note that the frequency of a detection signal obtained
from recording start position determination mark 141 is
much higher than that of the track error detection
5   signal.  For this reason, by frequency-separating these
two signals, mark 141 can be easily detected.  Since
the two signals have a large frequency difference, the
adverse influence of the presence of mark 141 on the
track error detection signal can be reduced.

10      A wobbled pattern (repeated pattern of $2\tau$ and $\tau$)
of the recording start position determination mark 141
portion is different from that (repeated pattern of $\tau$
alone) of a portion other than the mark.  That is, the
mark 141 portion has a unique wobbled pattern (a kind
15   of address).  For this reason, the detected "repeated
pattern of $2\tau$ and $\tau$" can be reliably determined
(specified) as mark 141.

Since the embodiment of the present invention
records data using CLV, gaps 111 have different
20   positions in the direction of rotation angle depending
on radial positions of information storage medium 9,
and the position of recording start position
determination mark 141 in the direction of rotation
angle shifts accordingly, as shown in FIG. 11.
25   By exploiting this feature, the radial position of
a location where the head currently traces can be
detected by detecting only the position of recording

start position determination mark 141 in the direction of rotation angle.

According to inequality (19) above, gap 111 or 115 must be set to have small physical length $\delta$ ($\delta 1$ or $\delta 2$ in FIG. 11). In this case, since gap 111 or 115 has sufficiently small physical length $\delta$, when data of only one continuous data recording unit 110 is rewritten, the rewrite start position is required to have high precision. If the rewrite start position precision is low, the previous and next continuous data recording unit positions may be overwritten upon rewriting only one continuous data recording unit 110.

In order to assure this high precision, in the embodiment shown in FIG. 12, recording start position determination mark 141 is recorded in advance on medium (recordable optical disc) 9 in the form of wobble modulation. This is a great characteristic feature of the embodiment of the present invention.

This recording start position determination mark 141 has the following features:

(a) Wobble modulation for wobbling a pre-groove which has a continuous groove shape and forms track 112 to the right and left is made. The width of the pre-groove which is wobbled to the right and left is maintained constant everywhere.

<Comment on a> Since the groove width is constant everywhere, even when a focused reproduction laser beam

is traced on recording start position determination
mark 141, the reflectance of light from that mark can
be maintained constant.  Therefore, recording marks 127
can be directly formed on recording start position

5    determination mark 141.  Even when signal reproduction
using a change in amount of light reflected by
recording marks 127, which are directly formed on
recording start position determination mark 141, is
made, a reproduction signal is free from the influence

10   of recording start position determination mark 141.

      (b)  Recording marks 127 corresponding to
immediately preceding continuous data recording unit
110a can be recorded in at least a portion in recording
start position determination mark 141.  Alternatively,

15   recording marks 127 can be recorded over whole
recording start position determination mark 141.

      <Comment on b>  In order to improve the recording
efficiency on information storage medium 9, the
physical length of gap 111b is preferably reduced as

20   much as possible.  As shown in FIG. 12, when recording
marks 127 corresponding to immediately preceding
continuous data recording unit 110a can be recorded in
at least a portion of recording start position
determination mark 141, information recording is

25   allowed on recording start position determination
mark 141, thus improving the recording efficiency and
increasing the recording capacity of the entire

information storage medium.

(c) The macroscopic duty ratio of wobble modulation of wobbled groove region 143 is matched with that of recording start position determination mark 141.

<Comment on c> In wobbled groove region 143, the ratio of right and left portions of wobbles is always set at 50% using a sine waveform. Likewise, the right-and-left wobbling ratio of recording start position determination mark 141 by wobble modulation is maintained at 50%. As a result, generation of an offset to a track error detection signal at the position of recording start position determination mark 141 can be prevented.

For example, when the right wobbling period of recording start position determination mark 141 is macroscopically longer than the left wobbling period, even when just the center of track 112 (pre-groove) is traced, a track offset, which is detected as a track error signal by the push-pull method as if a slightly left portion of track 112 were traced, is generated.

(d) Recording start position determination mark 141 is formed by wobble modulation while assuring the reference frequency ($1/\tau$: slot interval $\tau/2$) of wobble groove region 143.

<Comment on d> In wobbled groove region 143 in FIG. 12, a groove is wobbled at period $\tau$. The distance

from a position where the central position of a wobble

is passed until the central position is crossed

again is called a slot interval (having the same

meaning as the channel bit interval in general data).

5   Wobbled groove region 143 in FIG. 12 has a slot

interval of $\tau/2$.   The reference frequency upon

recording, the reference frequency used in PLL

(Phase Lock Loop) upon reproduction, or rotation

synchronization control of spindle motor 204 executes

10   PLL with reference to slot interval $\tau/2$ detected from

this wobbled groove.   If the reference frequency has

changed within recording start position determination

mark 141, PLL steps out in recording start position

determination mark 141, and the recording/reproduction

15   process and rotation control of the spindle motor

become unstable.   For this reason, the reference

frequency in recording start position determination

mark 141 is maintained constant to be $1/\tau$.

A pattern in recording start position

20   determination mark 141 shown in FIG. 12 alternately

repeats a wobble of period "$2\tau$" and that of period "t"

as in wobbled groove region 143 for four cycles.

In the wobbled portion having period "$2\tau$", the interval

from when a wobble exceeds the center once until it

25   passes the center again is just "$\tau$".   Since this value

corresponds to a value exactly twice slot interval $\tau/2$,

slot interval $\tau/2$ (i.e., reference frequency $1/\tau$) is

maintained unchanged in this region. As a result, PLL
is kept enabled irrespective of inside or outside
recording start position determination mark 141, and
the recording/reproduction process and rotation control
of the spindle motor can be stably done.

(e) Recording preparation region 142 is assured
between recording start position determination mark 141
and the recording start position of continuous data
recording unit 110b, so that the information
recording/reproduction apparatus becomes ready to
record while a focused beam spot passes by this
recording preparation region 142.

<Comment on e> The S/N ratio of a wobble
modulation signal obtained from the wobbled groove is
very poor, and the probability that the start position
of recording start position determination mark 141 is
always detected is low. Hence, in the embodiment of
the present invention, since a wobble with period "$2\tau$"
and that with period "$\tau$" are alternately repeated for
four cycles, the information recording/reproduction
apparatus can find recording start position
determination mark 141 somewhere in four cycles.

Once the information recording/reproduction
apparatus can find a position within recording start
position determination mark 141, the gate (detection
window) of a high-performance position detection
circuit is opened to detect the end position of

recording start position determination mark 141 with high precision.  Since the physical length of recording preparation region 142 is set to be a specific value in advance, if the end position of recording start

5      position determination mark 141 is detected, the recording process is started after an elapse of a time interval required to pass recording preparation region 142, which is set at the specific value, thus forming recording marks 127 from the head position of

10     continuous data recording unit 110b.  In this manner, since recording preparation region 142 is laid out immediately after recording start position determination mark 141, the end position detection precision of recording start position determination

15     mark 141 can be improved.  As a result, the low head position detection precision can be allowed, and a price reduction of a wobble modulation detection circuit can be achieved.  Since the end position detection precision of recording start position

20     determination mark 141 is improved, the start position precision of continuous data recording unit 110b can be greatly improved compared to the prior art.

Note that the groove pattern of recording preparation region 142 in FIG. 12 has the same

25     amplitude and period of that of wobbled groove region 143.

As the pattern of recording start position

determination mark 141, a single wobble with period "2τ" and a single wobble with period "τ" are alternately repeated for four cycles, as shown in FIG. 12.

However, the number of times of repetition in recording

5    start position determination mark 141 is not limited to four, but an arbitrary number of times of repetition can be selected.  The pattern of recording start position determination mark 141 is not limited to that shown in FIG. 12, but an arbitrary pattern can be set

10   as long as conditions (a) to (c) are satisfied within the scope (feature) of the present invention.

A method of overwriting and/or additionally writing data on information storage medium 9 using recording start position determination mark 141

15   pre-recorded on information storage medium 9, as shown in FIG. 12, will be explained below with reference to FIG. 13.

Controller 220 in FIG. 6 receives an instruction indicating a position where information recording is to

20   be done (i.e., recording location of recording information) on information storage medium 9 shown in FIG. 12 or 1 (step ST111).

Before information is recorded or rewritten on information storage medium 9, the position of recording

25   start position determination mark 141 in the direction of rotation angle at the radial position where recording or rewrite is made is predicted on the basis

of the recording location instructed in step ST111
(step ST112).

After the position of mark 141 is predicted, data
(corresponding to recording information 114 in FIG. 1
or 133, 134 in FIG. 8/10) of continuous data recording
unit 110 (131 in FIG. 8 or 137, 138 in FIG. 10) is
generated (step ST113). VFO field 113 is appended to
the head of data of continuous data recording unit 110
generated in this way (step ST114).

Subsequently, the recording start position
(the position predicted in step ST112) is accessed
(step ST115). In this access, it is determined if
the unique pattern (repeated pattern of 2τ and τ) of
recording start position determination mark 141 is
detected at the predetermined angular position
(the position predicted in step ST112) (step ST116),
thus checking if the predetermined radial position has
been reached, or if a track error has occurred during
tracing. If mark 141 cannot be detected at the
predetermined position (NO in step ST116), it is
determined that access cannot reach the predetermined
position or a track error has occurred during tracking,
and the access process is executed again (step ST115).

As described above, in the example shown in
FIG. 12, since an identical pattern (repeated pattern
of 2τ and τ) is repeated four cycles as recording start
position determination mark 141, the information

recording/reproduction apparatus in FIG. 6 can find
mark 141 somewhere in four cycles. If the information
recording/reproduction apparatus finds a position
within recording start position determination mark 141
5 (YES in step ST116), the gate (detection window) of
a high-performance position detection circuit in the
information recording/reproduction apparatus is opened
to begin to prepare for detection of the end position
of recording start position determination mark 141 with
10 high precision (step ST117). That is, if the unique
pattern of recording start position determination mark
141 is detected (YES in step ST116), recording
preparation is made during a period which has a pattern
end point of mark 141 as a start point and has a
15 duration corresponding to the length of recording
preparation region 142 (step ST117).

As shown in FIG. 12, since no wobble signal with
period "2τ" appear within recording preparation region
142, the boundary region between recording start
20 position determination mark 141 and recording
preparation region 142 can be detected by utilizing
this change in pattern.

Upon detection of the end position of recording
start position determination mark 141 (boundary
25 position between mark 141 and recording preparation
region 142), the control waits for an elapse of
a predetermined time interval (a period corresponding

to the length of recording preparation region 142)
required to pass recording preparation region 142, and
a continuous recording process corresponding to the
length of continuous data recording unit 110 is

5     executed (step ST118).

During recording (NO in step ST119), steps ST115
to ST118 are repeated. If data to be recorded does not
remain (YES in step ST119), the process in FIG. 13
ends.

10     FIG. 14 is a flow chart for explaining a forming
process of gap $\delta$ in the recording method according to
the embodiment of the present invention. In this
recording method, optical disc 9 which has wobbled
grooves along spiral tracks 112, and continuously

15     undergoes data recording for respective recording units
(ECC blocks) along tracks 112 while being rotated is
used.

Data for one ECC block ((f), (g) of FIG. 4) is
generated (step ST20), and recording marks 127

20     corresponding to the generated data are formed on track
112 of disc 9 (step ST21).

Gap $\delta$ (e.g., 111d in FIG. 10) is formed after the
end of the recorded ECC block (e.g., 130b in FIG. 10),
and the head of the next ECC block (e.g., 130c in

25     FIG. 10) is laid out (step ST22). Recording marks 127
for the next ECC block (130c) are formed on track 112
(step ST23). The aforementioned operations (steps ST20

to ST23) are repeated during recording (NO in step ST24).

In the process shown in FIG. 14, when data recording is done (step ST23) while forming predetermined gap δ between neighboring ECC blocks along track 112 (step ST22), the recording system (202 to 208) and rotation driving system (204, 214, 215) in FIG. 6 are controlled so that gap δ satisfies "$\delta \geq \tau f$" where $\tau$ is the wobble period of the wobbled groove and $f$ is the allowable rotation nonuniformity of rotation driving.

Furthermore, the recording system (202 to 208) and rotation driving system (204, 214, 215) in FIG. 6 are controlled to satisfy at least one of inequalities (4) to (6), inequality (7) or (8), and inequality (19).

Note that the present invention is not limited to the aforementioned embodiments, and various modifications may be made without departing from the scope of the invention when it is practiced. The respective embodiments may be combined as needed as long as possible, and combined effects can be obtained in such case.

Furthermore, the embodiments include inventions of various stages, and various inventions can be extracted by appropriately combining a plurality of required constituent elements disclosed in this application. For example, even when some required constituent

elements are deleted from all the required constituent elements disclosed in the embodiments, the deleted elements are compensated for as needed by known techniques when the extracted invention is practiced.

<Gist of respective embodiments>

[Basic point]

Data are continuously recorded for respective ECC blocks (recording units) along tracks 112 on information storage medium 9, and gaps $\delta$ are formed between neighboring ECC blocks (recording units) along tracks 112 (FIGS. 1, 12, and the like).

[Peripheral point]

(a) An allowable minimum value that $\delta$ can assume is specified (inequality (8) and the like);

(b) An allowable maximum value that $\delta$ can assume is specified (inequality (6) and the like); and

(c) When the allowable maximum value that $\delta$ can assume is exceeded, the gap positions of neighboring recording units are shifted between neighboring tracks (FIGS. 8, 10, and the like).

As described above, according to the embodiments of the present invention, the following effects can be obtained in correspondence with the following arrangements.

<1A> An information storage medium which has a wobbled groove along spiral tracks (112) and continuously undergoes data recording for respective

predetermined recording units (ECC blocks) along the

tracks (112) while being rotated, characterized in that

the continuous data recording can be done to form

a predetermined gap δ between the neighboring

5       predetermined recording units (ECC blocks) along

the tracks (112), and the predetermined gap δ satisfies

"δ ≥ τf" where τ is the wobble period of the wobbled

groove and f is the allowable rotation nonuniformity of

rotation.

10      <1B> An information recording method that uses

an information storage medium which has a wobbled

groove along spiral tracks (112) and continuously

undergoes data recording for respective predetermined

recording units (ECC blocks) along the tracks (112)

15      while being rotated, characterized in that upon

executing the continuous data recording to form

a predetermined gap δ between the neighboring

predetermined recording units (ECC blocks) along the

tracks (112), the predetermined gap δ satisfies "δ ≥ τf"

20      where τ is the wobble period of the wobbled groove and

f is the allowable rotation nonuniformity of rotation.

<1C> An information recording/reproduction

apparatus that uses an information storage medium which

has a wobbled groove along spiral tracks (112) and

25      continuously undergoes data recording for respective

predetermined recording units (ECC blocks) along the

tracks (112) while being rotated, and comprises

a spindle motor (204) for rotating the information storage medium (9), recording system means (202 - 208) for forming recording marks (127) for respective predetermined recording units (ECC blocks) on the tracks (112) of the information storage medium (9) rotated by the spindle motor (204), and reproduction system means (202, 203, 213 - 209) for reading information of the recording marks (127) from the information storage medium (9), characterized in that a gap $\delta$ which satisfies "$\delta \geq \tau f$" where $\tau$ is the wobble period of the wobbled groove and f is the allowable rotation nonuniformity of the spindle motor (204) is formed between the neighboring predetermined recording units (ECC blocks) along the tracks (112).

According to the arrangements of <1A> to <1C>, since recording is done to form a gap ($\delta$) between neighboring predetermined recording units (ECC blocks), two successive recording units can be prevented from overlapping even when a rotation driving mechanism (spindle motor) suffers rotation nonuniformity, and recorded data can be prevented from being destroyed (due to destruction of some recording marks when an overlapping portion is formed), thus assuring high data reliability. Since no prepit headers are required unlike the prior art, the capacity can be increased accordingly.

<2A> An information storage medium characterized

in that upon continuously executing data recording for respective predetermined recording units (ECC blocks) along the tracks (112) on the information storage medium (9), recording can be done to form a gap ($\delta$)

5  between the predetermined recording units (ECC blocks) along the tracks (112).

<2B> An information recording method characterized in that upon continuously executing data recording for respective predetermined recording units

10  (ECC blocks) along the tracks (112) on the information storage medium (9), recording is done (ST22) to form a gap ($\delta$) between the predetermined recording units (ECC blocks) along the tracks (112).

<2C> An information recording/reproduction

15  apparatus characterized in that upon continuously executing data recording for respective predetermined recording units (ECC blocks) along the tracks (112) on the information storage medium (9), recording is done to form a gap ($\delta$) between the predetermined recording

20  units (ECC blocks) along the tracks (112).

According to the arrangements of <2A> to <2C>, since recording is done to form a gap ($\delta$) between neighboring predetermined recording units (ECC blocks), two successive recording units can be prevented from

25  overlapping even when a rotation driving mechanism (spindle motor) suffers rotation nonuniformity, and recorded data can be prevented from being destroyed

(due to destruction of some recording marks when an overlapping portion is formed), thus assuring high data reliability. Since no prepit headers are required unlike the prior art, the capacity can be increased

5 accordingly.

<3A> An information storage medium characterized in that the information storage medium (9) is a one-sided, recording multilayer (122, 123) type disc-shaped medium (9) having spiral tracks (112)

10 with a track pitch Pt, data recording is optically done on the tracks (112) with the track pitch Pt via an objective lens (121) having a numerical aperture NA and an intermediate layer (124) having a refractive index n and thickness t, and a length $\delta$ of the gap

15 present between the predetermined recording units (ECC blocks) satisfies "$\delta \leq \pi(D + Pt) D/Pt$" (for $D = 2t \tan\{\sin^{-1}(NA/n)\}$).

<3B> An information recording method characterized in that an information storage medium (9)

20 is a one-sided, recording multilayer (122, 123) type disc-shaped medium (9) having spiral tracks (112) with a track pitch Pt, data recording is optically done on the tracks (112) with the track pitch Pt via an objective lens (121) having a numerical aperture NA

25 and an intermediate layer (124) having a refractive index n and thickness t, and a length $\delta$ of the gap present between the predetermined recording units

(ECC blocks) satisfies "$\delta \leq \pi(D + Pt)\ D/Pt$" (for $D = 2t\ \tan\{\sin^{-1}(NA/n)\}$).

<3C> An information recording/reproduction apparatus characterized in that an information storage medium (9) is a one-sided, recording multilayer (122, 123) type disc-shaped medium (9) having spiral tracks (112) with a track pitch Pt, data recording is optically done on the tracks (112) with the track pitch Pt via an objective lens (121) having a numerical aperture NA and an intermediate layer (124) having a refractive index n and thickness t, and a length $\delta$ of the gap present between the predetermined recording units (ECC blocks) satisfies "$\delta \leq \pi(D + Pt)\ D/Pt$" (for $D = 2t\ \tan\{\sin^{-1}(NA/n)\}$).

According to the arrangements of <3A> to <3C>, in a one-sided, two-recording layer type information storage medium on which information can be read from a plurality of recording layers from one surface side, even when the already recorded portion and non-recorded portion have a light reflectance difference, inter-layer crosstalk due to the influence of the presence/absence of recording marks on the other recording layer can be greatly reduced, and high reliability of a reproduction signal can be assured.

<4A> An information storage medium characterized in that upon continuously executing data recording for respective recording units (ECC blocks) along spiral

tracks (112) on a disc-shaped information storage
medium (9) having a center of rotation (center of 10),
recording is done to form a gap ($\delta$) between the
predetermined recording units (ECC blocks) along the

5    tracks (112), and an angular position (A) of the gap
($\delta$) formed on one of at least one pair of neighboring
tracks (112a, 112b) of the tracks (112) with respect to
the center of rotation (center of 10) is different from
an angular position (B) of the gap ($\delta$) formed in the

10    other (112b) of the neighboring tracks with respect to
the center of rotation (center of 10).

    <4B>  An information recording method that
continuously executes data recording for respective
recording units (ECC blocks) along spiral tracks (112)

15    on a disc-shaped information storage medium (9) having
a center of rotation (center of 10) to form a gap ($\delta$)
between the predetermined recording units (ECC blocks)
along the tracks (112), characterized in that an
angular position (A) of the gap ($\delta$) formed on one of at

20    least one pair of neighboring tracks (112a, 112b) of
the tracks (112) with respect to the center of rotation
(center of 10) is different from an angular position
(B) of the gap ($\delta$) formed in the other (112b) of the
neighboring tracks with respect to the center of

25    rotation (center of 10).

    According to the arrangements of <4A> and <4B>, in
a one-sided, two-recording layer type information

storage medium on which information can be read from a
plurality of recording layers from one surface side,
even when the already recorded portion and non-recorded
portion have a light reflectance difference,

5   inter-layer crosstalk due to the influence of the
presence/absence of recording marks on the other
recording layer can be greatly reduced, and high
reliability of a reproduction signal can be assured.

<5A>  An information storage medium which is a

10   recordable information medium (9) on which data
recording is continuously done to form a predetermined
gap (δ) between neighboring predetermined recording
units (ECC blocks) along tracks (112), characterized in
that a mark (141; a unique pattern which repeats itself

15   a plurality of number of times at τ + 2τ); a kind of
address pattern) which indicates a recording start
position for the continuous data recording for
respective predetermined recording units (ECC blocks)
is pre-recorded by wobble modulation of the tracks

20   (112).

According to the arrangement of <5A>, the
following effects (A) to (C) are obtained:

A)  Since the mark indicating the recording start
position for continuous data recording is present along

25   the tracks on the information storage medium, and the
recording start position can be set using that mark,
the recording position on the information storage

medium can be accurately determined.

B) Since the recording start position can be accurately set by effect (A), length δ of each gap region can be reduced. As a result, the recording capacity (recording efficiency) of the information storage medium can be improved.

In other words, when length δ of each gap region is reduced, and the recording start position precision is low, rewrite data may be partially overwritten on already recorded data (may destroy already recorded data) before and after data to be rewritten upon writing for respective continuous recording units. Since such problem can be avoided using the aforementioned mark, length δ of each gap region can be reduced.

C) When the mark indicating the recording start position is pre-recorded by wobble modulation, even when recording marks are recorded on the mark indicating the recording start position, no influence of a wobble modulation signal is superposed on a reproduction signal of these recording marks (unlike in the conventional prepit type). Therefore, since recording marks can be recorded on the mark indicating the recording start position, the recording efficiency can be improved, and the recording capacity of the information storage medium can be increased.

<6A> An information recording method

characterized in that the information storage medium of <5A> is used, and after a mark position indicating a recording start position for continuous data recording is detected (YES in step ST116), continuous recording

5     is started.

<6B>  An information recording apparatus characterized in that the information storage medium of <5A> is used, and after a mark position indicating a recording start position for continuous data recording

10    is detected (YES in step ST116), continuous recording is started.

According to the arrangements of <6A> and <6B>, the following effects (D) to (F) are obtained:

D)  Since the mark indicating the recording start

15    position for continuous data recording is present along the tracks on the information storage medium, and the recording start position can be set using that mark, the recording position on the information storage medium can be accurately determined.

20    E)  Since the recording start position can be accurately set by effect (D), length $\delta$ of each gap region can be reduced.  As a result, the recording capacity (recording efficiency) of the information storage medium can be improved.

25    In other words, when length $\delta$ of each gap region is reduced, and the recording start position precision is low, rewrite data may be partially overwritten on

already recorded data (may destroy already recorded data) before and after data to be rewritten upon writing for respective continuous recording units. Since such problem can be avoided using the

5  aforementioned mark, length $\delta$ of each gap region can be reduced.

F)  When the mark indicating the recording start position is pre-recorded by wobble modulation, even when recording marks are recorded on the mark

10  indicating the recording start position, no influence of a wobble modulation signal is superposed on a reproduction signal of these recording marks (unlike in the conventional prepit type).  Therefore, since recording marks can be recorded on the mark indicating

15  the recording start position, the recording efficiency can be improved, and the recording capacity of the information storage medium can be increased.